Emissivity: The Unknown Factor

Understanding Thermal Calculations to Save Money and Energy

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Revised Copy

Recently, a client, who is a plant manager for a major oil refinery, asked for help to understand how the amount of refractory and insulation lining system recommended for his flues and waste heat boiler by his supplier/contractor was calculated and what questions he should ask. I asked him what he knew about emissivity. He knew only that it was a measure of reflection or something to that effect.

I explained that emissivity is a key factor to understanding heat flow calculations and saving energy and money. The other important factors are wind velocity, ambient air temperature, surface temperature, thermal conductivity, or "K" value, and operating temperature. Proper calculation of the insulation and refractory (thicknesses and material types) will save money at the initial installation because he will only be paying for what he needs. As a long-term investment, this client will save energy and money by minimizing the amount of heat loss that radiates from the outer casings. By understanding emissivity, he will use less fuel to reach and maintain the waste heat boiler's operating conditions.

The following discussion, while not the whole story on emissivity, might simply shed some light on its value in determining the right insulation and refractory requirements for maximum savings.

Emissivity Defined

Emissivity is a measure of the ability of a material to radiate energy. It is expressed as a ratio (decimal) of the radiating ability of a given material to that of a black body.[1] A black body emits radiation at the maximum possible rate at any given temperature, and has an emissivity of 1.0. The values of emittance for various metals are published and so are undisputed. I suggest that the emissivity value used for the calculation be based on the current conditions of the materials being installed (i.e. reusing existing outer casing or lagging or installing new lagging or casing). More than just knowing the definition of emissivity, however, it is important to understand where and how this value can be used or misused in the calculation of insulation thickness.

Calculating Insulation Thickness

A good way to understand the role of emissivity in calculating insulation and refractory material thickness is to use good old- fashioned hand calculations. The formula below can be used for flat surfaces:

$$thickness = \left[\frac{(operating \text{ deg } F - surface \text{ deg } F)}{(heatloss\ Btu)} \right] \text{ x } (K\ value)$$

To find the elusive emissivity factor, the formula must be broken down further:

$$thickness = \left[\frac{(operating \text{ deg } F - surface \text{ deg } F)}{(1 + .225 \text{ x } velocity\ (fps)) \text{ x } (surface \text{ deg } F - ambient \text{ deg } F) + (0.1714 \text{ x } EMISSIVITY) \text{ x } \left[\frac{(surface \text{ deg } F + 460)^4}{(100)^4} - \frac{(ambient \text{ deg } F + 460)^4}{(100)^4} \right]} \right] \text{ x } (K\ value)$$

This gives the two basic components of Btu or heat loss portion, which are convection (in this case natural convection) and radiant values. In the radiant component of the Btu value we find emissivity.

This thermal calculation seems quite complicated, and with all the calculation software on the market today,[2] we should be glad that we no longer have to hand calculate. However, these computer programs require the same input to calculate heat flow. They all ask for velocity, ambient air temperature, surface temperature, and operating temperature. Most have built-in K values for the types of insulation and refractory to be used, or these values can be easily entered.

Variables of Calibration

So, what affects the insulation thickness calibration? The most obvious factor is the K value. A higher K value causes the calculation to have a greater insulation thickness. By using the mean value of the insulating material, we get a lower K value, and therefore, a lower insulation thickness. To find the K value:

1. Find the mean temperature:

$$\frac{(\text{operating temp.} + \text{surface temp.})}{2}$$

2. Identify value of K on published charts

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The K value of insulation has not changed dramatically over the years. As R.L. Schneider, a pioneer in heat transfer calculations, wrote "...since it is harder to keep improving insulation by decreasing the K value, let's increase the thickness when necessary."[3] If this is still true, then the only other variable that can affect the outcome of the insulation thickness calculation is emissivity.

Factoring Economic and Energy Savings

By understanding the emissivity factor, you can compare labor and material costs at various insulation thicknesses. That is the easy part of determining economic savings. The more difficult part is to relate that to energy savings, but this is the key. Think of insulation and refractory as an investment in energy savings down the road. "The greater the cost of insulation, the smaller the cost of heat loss," explained J.F Malloy,[4] in *Thermal Insulation.* That is, savings on heat loss occur when insulation thickness is increased; however initially, there is a greater installation cost for that increase of insulation thickness.

A Little Knowledge Pays Off

With a better understanding of emissivity, my client felt that he could evaluate the insulation and refractory design with confidence. The next time he talked with his supplier/contractor, he could ask informed questions, such as:

- Was the K value based on mean temperature?
- What external wind velocity was used?
- What emittance was used to calculate the insulation and refractory thickness?

Knowledge is everything! Knowing more about the calculations helped my client obtain the proper material type at the right thickness. He found that the design was insufficient due to incorrect emissivity and wind velocity factors. As a result, he kept the initial installation costs down by paying only for what he needed (short-term cost savings). In addition, heat loss in the plant has been minimized, which keeps fuel costs down (long-term energy savings). The end result is a thermally efficient and cost-effective installation of a refractory and insulation lining system for his flues and waste heat boiler. Thus proving what Mr. Malloy also wrote: "Thermal insulation installed to save energy also saves money at the rate that is essential for efficient plant operation."

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[1] ASTM C-680-89, page 13, Appendix A.
[2] Download DOE/NAIMA's 3E Plus insulation thickness software at **www.oit.doe.gov/bestpractices/software_databases/software.shtml.**
[3] *Fundamental Heat Transfer,* R. L. Schneider, 1961.
[4] *Thermal Insulation,* J.F. Malloy, 1969.